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[54] **STACKING ARRANGEMENT WHICH PROVIDES SELF-BIASING FOR SINGLE WALL DOMAIN ORGANIZATIONS**

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[52] **U.S. Cl.** .....**340/174 TF,** 340/174 QA, 340/174 S

[51] **Int. Cl.**.....**G11c 11/14**

[58] **Field of Search** .....340/174 TF

[56] **References Cited**

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[57] **ABSTRACT**

Large capacity memory systems employing single wall domain devices comprise an arrangement in which layers, of materials in which domains can be moved, are stacked to form a compact component. A stacking arrangement is described which eliminates the necessity of an externally supplied bias field normally present, for practical purposes, in single wall domain devices.

8 Claims, 3 Drawing Figures

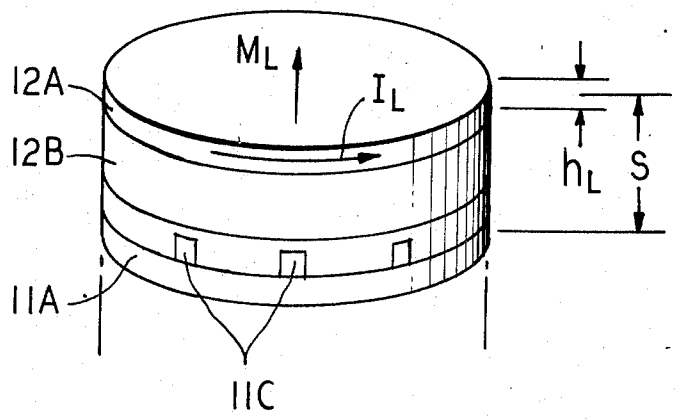


FIG. 1

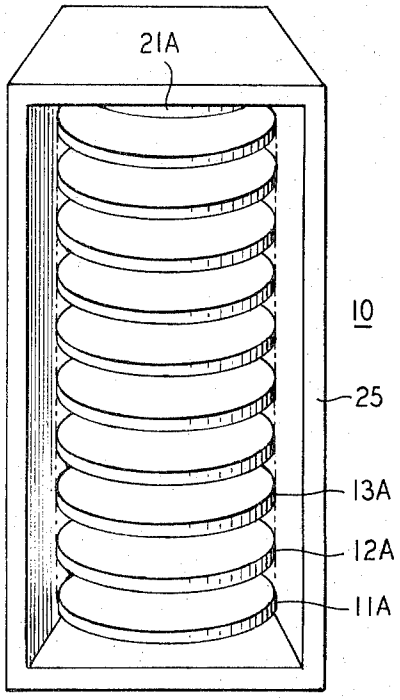


FIG. 2

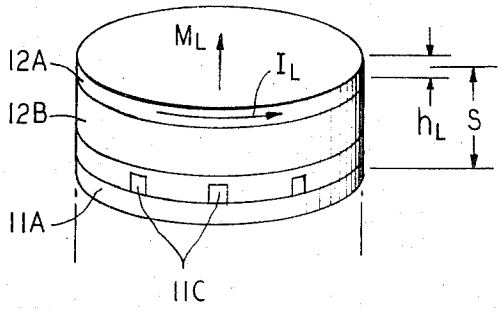
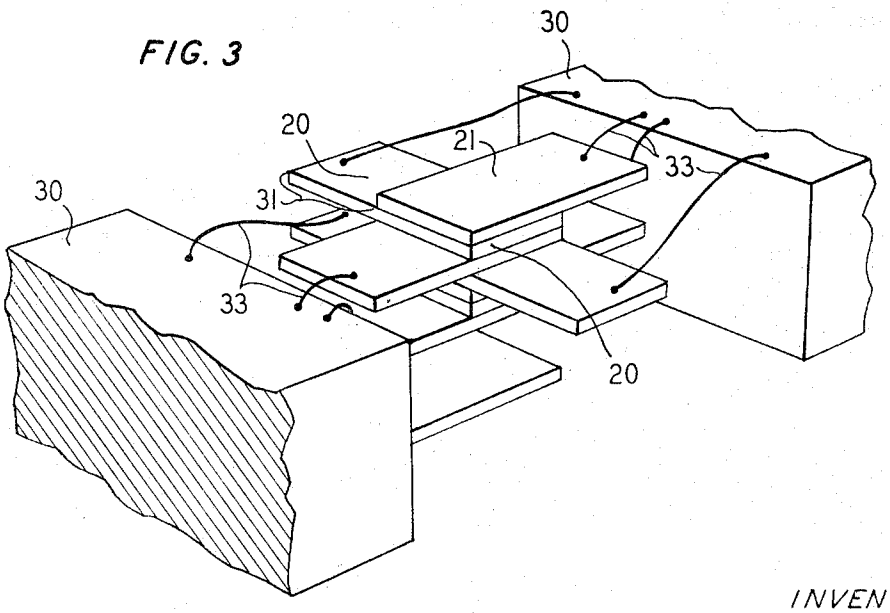


FIG. 3



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STACKING ARRANGEMENT WHICH PROVIDES SELF-BIASING FOR SINGLE WALL DOMAIN ORGANIZATIONS

FIELD OF THE INVENTION

This invention relates to data processing arrangements and more particularly to such arrangements in which information is stored as patterns of single wall domains.

BACKGROUND OF THE INVENTION

A single wall domain is well known in the art to comprise a reverse magnetized domain encompassed by a single domain wall which closes on itself in the plane of a layer of material in which such a domain can be moved.

The movement of a domain in a suitable layer is in response to a magnetic field generated at a position offset from the position occupied by the domain. A variety of techniques for moving domains are known, the most familiar being externally pulsed conductor patterns on the surface of the layer and alternatively a pattern of magnetically soft material (viz. the familiar T-bar overlay) which responds to a rotating uniform in-plane field to displace the domains. The latter arrangement is commonly referred to as a "field access" arrangement.

Whichever propagation arrangement is employed, the operating margins are enhanced by a bias field which maintains the domains at a constant diameter in the middle of the range of possible diameters characteristic for a domain in the layer in which the domain is moved. A simple arrangement for achieving a suitable bias field is by means of a permanent magnet. Another means is by a current-carrying coil. Since most suitable materials for the movement of single wall domains have their magnetization normal to the plane of the layer in which domains are moved, the bias field also is normal to that plane and of a polarity to constrict domains to the preselected diameter.

It is important that the bias field be uniform over the layer so that domain diameters do not vary when domains are moved. Accordingly, the magnets or coils which supply the field are of special design to provide suitable fields.

Domain propagating overlay circuits have been made to provide packing densities of millions of bits per square inch. Due to the fact that suitable layers an inch on a side have not yet been produced in commercial quantities and due to the desire for relatively large capacity systems, it has been found desirable to stack a number of layers in which domains can be moved to provide an arrangement having a capacity of 15 million bits or more.

The problem of providing a suitably uniform bias field for such a stack of layers is relatively complicated. One solution would be to employ a large magnet where the stacked arrangement would occupy a position in the jaws of the magnet. This would require a large and awkward arrangement. Alternatively, a pair of magnets of special shape could be positioned at the ends of the stack. On the other hand, a laminated magnetic enclosure where various layers thereof have fields which to some extent compensate one another could be employed. But these arrangements would require the forming of the proper shape for the magnets which could be costly. Other possible arrangements would include magnetic layers interspersed between layers in which single wall domains can be moved or exchange coupled overlays on the domain carrying layers—relatively attractive arrangements.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with this invention, on the other hand, layers of material in which single wall domains can be moved are stacked in a manner to bias themselves without additional permanent end or interleaved magnets or coils. Specifically, the invention stems from the recognition that layers of materials in which single wall domains can be moved supply magnetostatic fields which can be used to supply the desired bias field when a number of layers are stacked together rather than supplying the field from some external source as described above.

In one embodiment of this invention, layers in which domains can be moved are stacked such that next adjacent layers are spaced apart ideally a distance twice the diameter of a domain. For Garnet layers, domains have typically 7-micron diameters leading to inter-layer spacings of 14 microns.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a projection view of layers, in which single wall domains can be moved, stacked in accordance with this invention;

FIG. 2 is a projection view of a portion of the stack of FIG. 1; and

FIG. 3 is a projection view of a practical arrangement of layers stacked in accordance with this invention and exposed for external interconnection.

DETAILED DESCRIPTION

FIG. 1 shows a stack arrangement **10** in accordance with this invention. The arrangement comprises a stack of layers **11A**, **12A**, etc. and **21A**, each of which is capable of having single wall domains moved therein. The means for moving domains in individual slices is not shown because it is well known and not necessary for an understanding of this invention. The stack is shown encompassed by an enclosure **25** of high permeability material to shield the stack from stray fields and to provide a return path for flux in a manner to ensure that the end layers of the stack are under the influence of the same field as the inner layers.

A representative layer of the stack arrangement of FIG. 1 is shown in FIG. 2. The origin of the bias field supplied by the layers can be understood if the layers are viewed in terms of the familiar amperian current model. In accordance with this model, the magnetic field B created by the stack of wafers is identical to the field inside a solenoid with currents flowing at the edge of the wafers. The amperian current I_L associated with each layer equals M_L, the magnetization of the layer times the thickness of the layer h_L divided by the permeability, μ_0 of free space. The average field inside a uniform stack is given by

$$B=\frac{I_L\mu_0}{S} \tag{1}$$

where S is the distance between layers. If we allow a factor of $(1-2f)$ where f equals the fraction of a layer area occupied by domains, typically 0.05 inch for a layer having an area of 1 square inch, we can express Equation (1) as

$$B=\frac{(1-2f)M_Lh_L}{S} \tag{2}$$

The bias field employed in a practical situation is typically one-fourth of the magnetization of the layer—about $(M_L/4)$. Consequently, the spacing S_o between layers for complete self-biasing can be obtained from

$$S_o=(1-2f)\,4h_L\approx 2d \tag{3}$$

where d is the domain diameter (approximately twice the layer thickness).

The arrangement, of course, is characterized by additional magnetic fields associated with domains moving in layers above and below the layer of FIG. 2. Such domains, at a distance of $2d$, create a field of about the magnitude of a field used to propagate a domain. Domains directly aligned with one another in adjacent layers will tend to lock together because of this field whereas domains whose axes are displaced more than about 2 diameters will repel each other slightly. Such effects are reduced in accordance with this invention by spacing the layers sufficiently far apart such that the effects are negligible. A spacing of three domain diameters is suitable. But a spacing of $2d$ is ideal and practical even with the additional fields due to individual domains being present.

In practice, Garnet films are formed epitaxially on a suitable substrate such as a nonmagnetic Garnet to provide a layer such as **12A** of FIG. 1. Typically, the substrate is 10 microns

thick and the epitaxial layer is 4 microns thick. The relative thicknesses are seen in FIG. 2 from representations of the layers designated 12A and 12B there. An additional spacing of up to 2 microns is occupied by conductors for controlling domain movement in an individual layer. The conductors are represented as rectangles 11C in FIG. 2. For T-bar propagating arrangements, layers of only about 1000 angstrom units need be provided rather than the 2 microns necessary for conductors. It should be clear from FIG. 2, consequently, that spacings of between two and three layer thicknesses are presently achievable. FIG. 1 shows only layers 11A, 12A, through 21A. If the A layers are understood to represent only the epitaxial layers, the stacking of elements as shown in FIG. 2 can be seen to produce a solid stack in which the epitaxial layers are spaced apart as required.

In situations where the spacings between layers in which domains are moved are greater than about four times the thickness of a domain carrying layer in the stack, the self-biasing field is reduced and supplemental fields are desired for optimum operation. Even in this situation, however, the design parameters for the provision of uniform fields are substantially reduced because a bulk of the requisite field is provided by the layers themselves and only an incremental field is provided by, say, an external permanent magnet. This supplemental field, for spacings of say eight times the layer thickness would equal a self-biasing field and thus would provide one-half the desired total bias field. For spacings of two domain diameters, the self-biasing field is $0.22 \times (M_s/\mu_0)$ and a supplemental field is unnecessary. For spacings of only one domain diameter (two layer thicknesses), the supplemental field again would be equal to the self-biasing field. In those cases where a supplemental field is desired, it may be provided conveniently by an exchange coupled overlay film assumed present, in such cases, in each of layers 11A, 12A, etc. of FIG. 1.

In practice where external leads are attached to conductors employed for moving domains in individual layers of the stack of FIG. 1, the individual layers conveniently are rectangular in geometry as shown in FIG. 3. The stack is placed in a suitable hole in a substrate 30 which is on the order of about 65 microns thick. The layers are stacked in a manner to cantilever each layer over the next lower layer to expose a portion of the next lower layer for external connection. For example, layer 21 of FIG. 3 is turned to expose contact area 31 of layer 20, the stack being upside down with respect to the arrangement of FIGS. 1 and 2. In this manner, contacts to printed circuitry (not shown) on substrate 30 are relatively simple to achieve as shown in the figure by leads 33. Spacings between similarly exposed contact areas are typically over 40 microns apart.

The cantilever arrangement, of course, is unnecessary for field access arrangements where field access rather than conductor access is used.

Moreover, layers useful for stacking initially are formed in a demagnetized condition. Consequently, when manufactured, the stack of layers is exposed to an initializing field normal to the plane of the layers for establishing the self-biasing condition. Such a field is provided by well-known external field supplying sources and is maintained by the layers themselves once so established.

What has been described is considered only illustrative of the principles of this invention. Therefore, various and numerous other arrangements may be devised by one skilled in the art in accordance with those principles within the spirit and scope of this invention.

What is claimed is:

1. A magnetic arrangement comprising a stack of layers of magnetic material in each layer of which single wall domains can be moved, each of said layers having a preferred direction of magnetization out of the plane of layer and a thickness h, and means for securing said layers in fixes spaced apart relationship with respect to one another distances of about $4h$ whereby said layers are substantially self-biasing in the absence of an external bias field when set into a like direction of magnetization.

2. An arrangement in accordance with claim 1 wherein said layers comprise films deposited on substrates having thicknesses greater than h, each of said layers having associated therewith a planar arrangement for moving domains therein, wherein said means for securing said layers comprising said substrates and said planar arrangements in a solid stack arrangement.

3. An arrangement in accordance with claim 2 wherein said planar arrangement comprises a planar pattern of magnetically soft elements which provide changing pole patterns for moving domains in the adjacent layer when a reorienting in-plane field is generated therein.

4. An arrangement in accordance with claim 2 wherein said planar arrangement comprises an electrical conductor pattern for generating changing magnetic fields for moving domains in the adjacent layer when selectively pulsed.

5. An arrangement in accordance with claim 4 wherein said layers are consecutively cantilevered for exposing said conductor pattern for external connection.

6. A magnetic arrangement comprising a stack of layers of magnetic material in each layer of which single wall domains can be moved, each of said layers having a preferred direction of magnetization out of the plane of the layer and a thickness h, and means for securing said layers in fixed spaced apart relationship with respect to one another distances such that the layers when set into a like direction of magnetization provide magnetostatic fields which are of a polarity to constrict said domains, said fields being of a magnitude to reduce an externally supplied bias field from a value otherwise necessary to construct each of said domains to a prescribed geometry.

7. A magnetic arrangement in accordance with claim 6 wherein said distances are between about $2h$ and $8h$ for providing a magnetostatic field equal to at least 50 percent of the bias field necessary to construct each of said domains to said prescribed geometry in the absence of said magnetostatic field.

8. A magnetic arrangement in accordance with claim 7 also including a high permeability enclosure thereabout.

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